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A TIME SERIES ANALYSIS OF LABOR TURNOVER

Frank P. Brechling

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A Time Series Analysis of Labor Turnover

Frank Brechling*

1. Introduction

Import penetrations of markets typically necessitate reductions in the employment levels of the affected domestic suppliers. These net reductions in employment can be subdivided conveniently into *displacements* and *unreplaced attritions*. Displacements are permanent separations initiated by employers and attributable to the import penetration. Attritions are all other permanent separations that may be due to voluntary quitting, retirement, death, disability, incompetence, or dishonesty. When employers refrain from replacing attritions they are termed unreplaced attritions. The essential difference between displacements and attritions arises from the nature of their costs. Displacements involve unexpected costs that, in the absence of compensation for them, must be borne involuntarily by the displaced workers. The costs of attritions, on the other hand, are anticipated and borne voluntarily by workers as part of the normal costs of obtaining and leaving jobs.[1] For this reason it is often suggested that displaced workers be compensated for their displacement costs, especially if the import penetration is attributable to a change in governmental policy. In the United States some compensation for displacement costs is provided for under the trade adjustment assistance program of the 1974 Trade Act.

The aim of the research underlying this paper has been to obtain estimates of displacements and unreplaced attritions in industries that experience permanent net reductions in employment. Such information may be helpful in the formulation of trade policies as well as for the evaluation of the trade adjustment assistance program.[2]

Several data bases have been used for the computation of displacements and unreplaced attritions.[3] In the research underlying the present paper, the *time series* data on labor turnover by industry published by the Bureau of Labor Statistics have been used. In part 2 of this paper a conceptual framework for and a description of these statistics are presented. The conceptualization of the labor turnover relationships also yields formal, operationally meaningful expressions for displacements and unreplaced attritions.

For the estimation of displacements and unreplaced attritions a model is required within which these labor flows or their components are linked to their determinants, in particular, to net changes in employment. Part 3 of this paper is devoted to the description, derivation, estimation and simulation of labor turnover models. This part is subdivided into four sections. In section 3A a turnover model with *exogenous quits*, which was developed and fitted by a previous investigator, is presented and its implications for displacements and unreplaced attritions are described. This model and the appropriate parameter estimates suggest that 79 percent of any net reduction in employment is accomplished by unreplaced attritions and only 21 percent by displacements.

These estimates of unreplaced attritions and displacements, however, depend crucially on the assumption of exogenous quits. By contrast, the model, which has been used in the major part of the research underlying this paper, incorporates quits as an *endogenous*

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*I am deeply indebted to my colleagues at the Public Research Institute for many helpful discussions of the seemingly insuperable problems encountered in the research underlying this paper. Kathy Classen, William Dewald, Paul Feldman, Harry Gilman, and Bruce Vavrichek read a previous draft of this paper and made many valuable comments. Their help is acknowledged gratefully. This paper is based on Frank P. Brechling "A Time Series Analysis of Labor Turnover," ILAB 75-19 which was completed in 1976.

[1]Costs of displacements and attritions have been estimated by Bale [1] and Jacobson [10].

[2]Although the research has here been motivated in terms of the consequences of trade liberalization measures, estimates of displacements and unreplaced attritions may be useful for many other purposes. Suppose, for instance, that a net reduction in employment is brought about by a regulation designed to protect the environment. The costs incurred by displaced workers would be a legitimate cost of the implementation of the regulation and, hence, it would be important to know the level of displacements and unreplaced attritions.

[3]See, for instance, Jacobson [9] who used Social Security data to estimate displacements and attritions in the steel industry.

variable. This model, which is described in section 3B, consists of several dynamically interdependent equations, designed to describe the behavior over time of all the relevant labor turnover categories.

The labor turnover model with endogenous quits has been fitted to the data for twenty-four manufacturing industries, but section 3C contains the empirical results for only two groups, namely total durable and total nondurable goods industries. The results lend considerable empirical support to the model with endogenous quits. The equations explaining new hires and layoffs by firms conform to the data especially well.

Since it is difficult to ascertain the full implications of a model that consists of several dynamically interdependent equations by analytical methods, its main implications for displacement and unreplaced attritions have been obtained by a simulation exercise. The industry in question is assumed to be initially in equilibrium and then it is disturbed by a permanent 10 percent reduction in output. The ensuing paths of employment and the labor turnover categories are then traced and estimates of displacements and unreplaced attritions are made. The results for total durable and total nondurable goods industries are reported in section 3D. They suggest that unreplaced attritions play only a secondary role in effecting net reductions in employment. Of four different estimates of unreplaced attritions, the highest one is 43 percent of the net reduction in employment, which is substantially below the 79 percent implied by the model with exogenous quits. The failure of unreplaced attritions to bring about much of the net reduction in employment occurs in spite of large reductions in new hires and is due to the sharp decline in voluntary quits. In other words, a decline in the demand for an industry's output and, hence, for labor discourages attritions so strongly that, despite large reductions in replacements, the level of unreplaced attritions cannot rise much.

In part 4 of this paper the main conclusions and major desirable extensions of the research are highlighted. The empirical results suggest that the extent to which costless unreplaced attritions can bring about net reductions in employment may be quite limited and this conclusion may well be at variance with the views held commonly by labor economists. To be sure, many problems of conceptualization, estimation, and interpretation remain to be solved. In particular, it seems desirable to disaggregate the data and to estimate and simulate models for many industries.

2. Concepts and Definitions

In part 2 the basic concepts and definitions of labor turnover as well as the main characteristics of the data used in the analysis are described. Such a description is a suitable introduction to the discussion of labor turnover models in part 3. The main labor turnover relationships are discussed in section A, and section B contains a description of the time series data.

A. The Basic Labor Turnover Relationships

Figure 1 illustrates the relationships among an industry's various gross and net flows of labor. Accessions A are all permanent and temporary additions to the payrolls of establishments in a specified time period. Separations S are all terminations of employment at establishments during the period. Thus accessions and separations measure the gross inflows and outflows of labor. Consequently the net change in employment equals the difference between accessions and separations

$$\Delta N = A_t - S_t, \tag{1}$$

where ΔN measures the net change in employment in period t.

It is helpful to distinguish between two main flows of labor in Figure 1. First, there is the upper counterclockwise flow, which contains workers who have been laid off. Layoffs L are terminations of employment, initiated by the employer because of economic conditions, such as lack of orders, and without prejudice to the employees. Laid-off workers initially join and, hence, raise the stock of laid-off employees SL who qualify for and are awaiting recall by their previous employers. Workers who leave the stock of laid-off employees may (1) be rehired by their previous employers and included in RH, a component of A, (2) be newly hired by other employers in the same industry and included in NH_1, a component of A, or (3) leave the industry altogether and be included in DIS_1. This basic identity among the variables can be stated formally:

$$L_t = \Delta SL + RH_t + NH_{1t} + DIS_{1t}, \tag{2}$$

where ΔSL stands for the net increase in the stock of laid-off workers in period t.

Two concepts of displacements can be derived from equation (2). First, displacements can be measured by DIS_1, the number of laid-off workers who leave the industry:

$$DIS_{1t} = L_t - \Delta SL - RH_t - NH_{1t}. \tag{3}$$

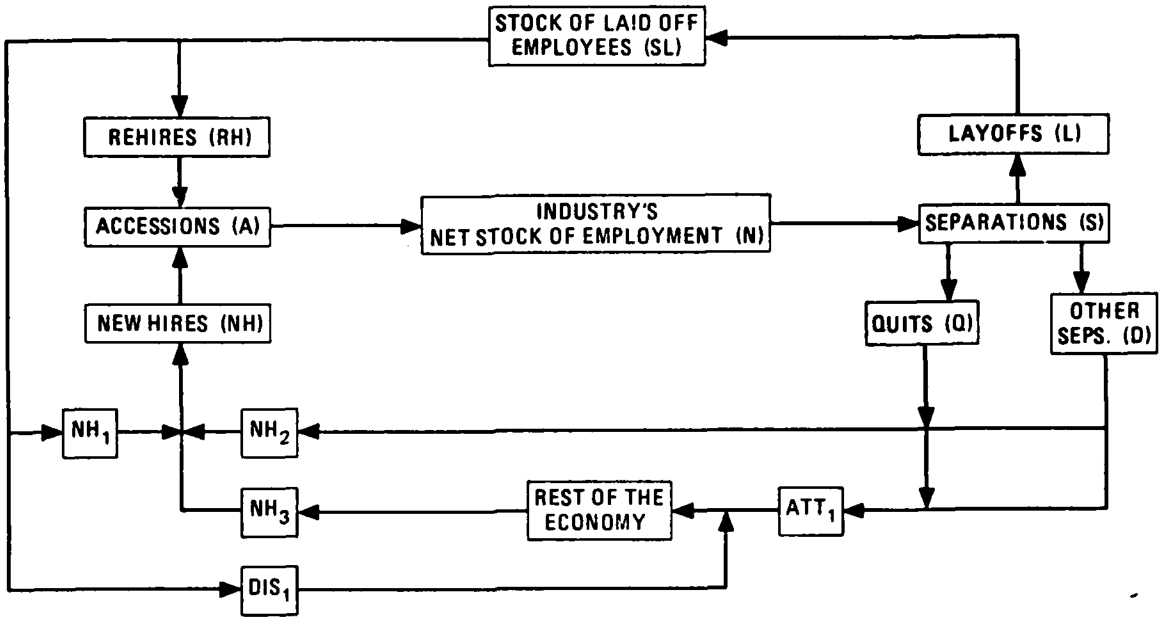

Figure 1
Gross Flows of Labor into and out of an Industry

Second, displacements can be measured by *DIS*, the number of workers who leave the industry plus the increase in the stock of laid-off workers:

$$DIS_t = DIS_{1t} + \Delta SL = L_t - RH_t - NH_{1t}. \quad (4)$$

The second basic flow of labor in Figure 1 is the lower clockwise one which contains quits Q and other separations D. Quits are terminations of employment initiated by employees for the purpose of changing to another job, searching for another job, or leaving the labor force. Other separations include discharges for reasons such as incompetence or dishonesty, as well as terminations due to retirement, death, and physical disability. Workers who are classified as quits or other separations may (1) find jobs in the same industry and appear in NH_2, a component of A, or (2) leave the industry and appear in ATT_1. This identity can be written as:

$$Q_t + D_t = NH_{2t} + ATT_{1t}. \quad (5)$$

As shown in Figure 1, total new hires consist of three components: laid-off workers who are hired by *new* employers in the same industry NH_1, workers in quits and other separations who find a job in the same industry NH_2, and workers who are hired from outside the industry NH_3:

$$NH_t = NH_{1t} + NH_{2t} + NH_{3t}. \quad (6)$$

The concept of unreplaced attritions can now be defined in terms of the labor turnover categories. For an industry, unreplaced attritions *ATT* measure the number of workers, classified as quits and other separations who leave the industry and are not replaced by new hires from outside the industry:

$$ATT = ATT_{1t} - NH_{3t}, \quad (7)$$

or, because of equations (5) and (6)

$$ATT_t = Q_t + D_t - NH_t + NH_{1t}. \quad (8)$$

By adding equations (4) and (8) it can easily be established that the sum of *DIS* and *ATT* must equal the net reduction in employment.

$$DIS_t + ATT_t = (L_t + Q_t + D_t) - (NH_t + RH_t)$$
$$= S_t - A_t = -\Delta N. \quad (9)$$

Similarly, by adding equations (3) and (8) it can be shown easily that the sum of DIS_1 and ATT must be equal to $-\Delta\ (N+SL)$.

B. The Time Series Data

The Bureau of Labor Statistics, in collaboration with the state employment security agencies, collects and publishes five monthly labor turnover series for 191 manufacturing industries. These five series are accessions, new hires, separations, quits, and layoffs.[4] The definitions used for these concepts by the BLS are virtually identical to those presented in the previous section.

Absolute numbers for the five turnover categories are obtained by the BLS each month for a sample of establishments in each industry. These figures are then converted into percentages by dividing them by the total number of employees who are on the sampled establishments' payrolls during the week containing the twelfth day of the month. The monthly percentage turnover series are published in *Employment and Earnings*.

For the purpose of the empirical research underlying the present paper, the published BLS turnover rates were converted into absolute numbers and then cumulated over three months, so that the basic data set consists of *quarterly absolute turnover levels*. Three other turnover series were constructed from the basic data set: rehires, other separations, and the stock of laid-off workers. Let us discuss these series in turn.

(1) Rehires were computed as the difference between accessions and new hires, or $RH = A-NH$. Because of the BLS definitions, this concept of rehires includes not only recalls of laid-off workers but also transfers from other establishments of the same company and employees returning from military service or unpaid leaves of absence.

(2) Other separations were computed as the difference between total separations and the sum of layoffs and quits, $D = S-Q-L$. Thus, other separations include dismissals initiated by the employer for reasons such as incompetence or dishonesty, as well as terminations due to military service, retirement, death, physical disability, and transfers to other establishments of the same company.

(3) The stock of laid-off employees SL is somewhat more complicated to compute than that of rehires and other separations. The gross inflow into SL consists of layoffs and part of the gross outflow consists of rehires. But unfortunately there is no published information on the other part of the gross outflow which in Figure 1 is measured by $NH_1 + DIS_1$. Hence, the other part of the gross outflow was assumed to be a constant proportion δ of the stock of laid-off workers. Let SL_t stand for the stock of laid-off employees at the end of period t. The following equation then describes how SL_t is determined by SL_{t-1}, δ, L_t, and RH_t:

$$SL_t = (1-\delta)SL_{t-1} + (L_t-RH_t), \qquad (10)$$

where L_t-RH_t measures the net layoffs in period t and and $(1-\delta)SL_{t-1}$ the number of employees in the stock both at the beginning and at the end of period t. Equation (10) implies that $NH_1+DIS_1 = \delta SL_{t-1}$. In order to compute SL_t assumptions have been made about the size of the initial stock SL_0 and the proportion δ. The initial stock was assumed to be approximately equal to the mean layoffs for a period of one to three months and the proportion δ was chosen between 0 and 0.3. These two assumptions permit the computation of a time series for SL_t. In the actual calculations SL_t was expressed as a proportion of the labor force, $SL_t/(SL_t + N_t)$. The assumptions about SL_0 and δ were changed until plausible time series for this proportion were generated. The occurrence of negative SL_t's proved to be a particular problem. In some industries rehires are so large in relation to layoffs that negative SL_t's could be avoided only by very large SL_0's and small δ's.[5]

No data are available or could be generated for some of the labor turnover categories mentioned in the description of Figure 1. In particular, no information exists on NH_1, NH_2, NH_3, DIS_1, and ATT_1. The lack of data on NH_1 is especially unfortunate because it plays a potentially important role in the definition of displacements and unreplaced attritions in equations (3), (4) and (8). In the actual computations of DIS_1, DIS, and ATT, it was necessary, therefore, to assume that $NH_1 = 0$. Moreover, since it is often appropriate to measure the labor turnover flows as *deviations* from some equilibrium or steady-state level, NH_1 need not necessarily be positive and, hence, nothing can be said about the direction of the bias in DIS_1, DIS, and ATT, which is caused by the omission of NH_1.

In order to give the reader an impression of the rough order of magnitude of the time series data on labor turnover, Table 1 has been prepared. It shows the sample means of the net change in employment and all the

[4] According to the questionnaire, which is sent to the sample of firms, form DL1219, the BLS requests and receives information also on a sixth turnover category, namely, discharges. This series, however, is not published separately.

[5] In a recent paper, Parsons and Fleisher [16] have argued that δ should be allowed to fluctuate over the business cycle. Moreover, their preliminary calculations seem to suggest that δ is significantly higher in prosperous than in depressed times. The above assumption of a constant δ is thus undesirable but unfortunately apparently unavoidable until better data become available.

Table 1
Mean Quarterly Turnover and Employment Variables for Total Durable and Nondurable Goods Industries

	Durables	Nondurables
Net change in employment, $\Delta N/N$ in percent	0.16	0.15
Accessions, A/N in percent	11.85	13.92
New hires, NH/N in percent	8.11	9.83
Rehires, RH/N in percent	3.74	4.09
Separations, S/N in percent	12.35	14.15
Quits, Q/N in percent	5.25	6.88
Layoffs, L/N in percent	4.47	5.11
Other separations, D/N in percent	2.62	2.16
Accessions-separations, $(A-S)/N$ in percent	−0.50	−0.23
Error in data, $Z/N = (\Delta N - A + S)/N$ in percent	0.66	0.38
Mean employment stock, N in thousands	10,705	7,750
Mean stock of laid-off employees, SL in thousands	518	258

Sample Periods: 1960.II to 1975.IV for durable goods industries; 1958.II to 1974.IV for nondurable goods industries.

labor turnover flows as percentages of the sample mean of the employment stock.[6] The latter and the mean stock of laid-off employees are also presented. The following characteristics of the data are worth noting.

First, the turnover flows are all quite large in relation to the net changes in employment. In particular, the sums of quits and other separations, which amount to 7.9 and 9.0 percent for the two industry groups, seem sufficiently large to suggest that unreplaced attritions are capable of playing an important role in effecting net reductions in employment levels.

Second, there seems to be an internal inconsistency in the data, which may cause problems in both the empirical estimation and the interpretation of the empirical results. According to equation (1), the net change in employment is equal to the difference between accessions and separations. However, the figures in Table 1 show that on average $A-S$ is negative and ΔN is positive. The percentage errors Z/N in the data amount to 0.66 and 0.38 for the durable and nondurable goods industries respectively. In absolute numbers these differences amount to just under 70,000 and 30,000 workers for the two industry groups. Although this inconsistency between the labor turnover and employment stock data has been recognized before, relatively little is known about its causes and sources.[7] In the empirical analysis underlying the present paper, the inconsistency in the data has been treated in two ways. In one it has been allowed to exist, so that the identity $\Delta N = A-S$ is not imposed in the empirical estimation. In the other the difference between ΔN and $A-S$ has been attributed alternatively to displacements or to unreplaced attritions so that the identity has been made to hold in the empirical estimation.

Third, rehires tend to be quite large in relation to layoffs. Thus, for both industry groups rehires average more than 80 percent of layoffs. This evidence suggests that, at least for the sample period under consideration, a large proportion of layoffs are temporary in the sense that they do not involve the severance of long-run employer-employee relationships.

3. Models of Labor Turnover

Relatively little research has been undertaken on the *time series* behavior of labor turnover in U.S. manufacturing industries.[8] Further, three previous investigators confined their analyses to only one labor turnover category: Barth [2] studied only layoffs; Mattila [11] and Parsons [15] only quits. For present purposes the previous work by Hamermesh [8] is the most relevant. For this reason his approach has been studied in detail as part of the research underlying the paper and the

[6]For the computation of the net change in employment, it is necessary to obtain an estimate of the level of employment at the end of the quarter. These estimates were obtained by computing the means of the employment levels in the last month of the quarter in question and the first month of the following quarter. Thus employment at the end of, for instance, the first quarter was set equal to the mean of the March and April employment levels.

[7]The difference between ΔN and $(A-S)$ is frequently attributed to the under-reporting of rehires, but this explanation does not seem to be wholly satisfactory because in many industries rehires are already very large in relation to layoffs.

[8]There are, however, quite a number of excellent *cross-section* analyses of labor turnover, of which the ones by Burton and Parker [6], Hall [7], Parsons [14], Pencavel [17, 18], and Stoikov and Raimon [19] seem to be the most noteworthy. One other interesting recent contribution is that by Toikka [20]. He uses time series data to study the probabilities of movements between employment, unemployment and nonparticipation. Toikka's main focus is his labor force participation, which is different from, but related to, the focus of the present study, namely the determinants of displacements and unreplaced attritions.

findings are summarized in section A.[9] In section B an altenative model is presented, which is similar in spirit to Hamermesh's but differs from it in crucial respects. It is estimated in section C and simulated in section D.

A. A Labor Turnover Model with Exogenous Quits

This section contains a condensed version of a working paper [4] in which Hamermesh's approach is analyzed and its implications for unreplaced attritions and displacements ascertained by means of simulation experiments.[10]

Hamermesh's model consists of the following five equations:

$$\log n = \alpha_0 + \alpha_1 \log n_{-1} + \alpha_2 X + \alpha_3 \dot{y}, \tag{11}$$

$$\log l = \beta_0 + \beta_1 \log l_{-1} + \beta_2 X + \beta_3 \dot{y}, \tag{12}$$

$$oa = \gamma_0 + \gamma_1 \, oa_{-1} + \gamma_2 l_{-2}, \tag{13}$$

$$os = \eta_0 + \eta_1 \, n_{-2}, \tag{14}$$

$$q = \mu_0 + \mu_1 \, (1/u^2) + \mu_2 \dot{u}, \tag{15}$$

where n, l, oa, os, and q stand for new hires, layoffs, other accessions, other separations, and quits, all measured as percentages of the employment stock. Further, $\dot{y}$ is the percentage change in output, u is the national unemployment rate, and $X = q - oa + os$. The time period to which the subscripts refer is one month.

For present purposes, two aspects of Hamermesh's model should be emphasized. First, crucial relationships have been specified entirely in terms of the proportionate growth rates of employment and output. Hence, the model does not yield any nontrivial comparative static predictions about the *level* of employment. Moreover, the actual level of current employment is not allowed to have an influence on labor turnover, so that, for example, new hires must rise with output growth, no matter whether the firm's *current level* of employment is excessive or deficient.

Second, quits are postulated to depend only on the national unemployment rate and its change, which are independent of the activities of the small industry the model describes. Thus quits are really assumed to be exogenous. This assumption is important for the computation of unreplaced attritions for the following reason: If quits are independent of the industry's activities, then a reduction in employment can be brought about relatively easily by reductions in new hires. If, by contrast, quits should *decline* in response to reductions in demand, then firms would have to offset these declines by further reductions in new hires in order to bring about a given cut in employment through unreplaced attritions, and firms may find it difficult to accomplish this.

Hamermesh's model, with his own parameter estimates, was simulated for several industries. For brevity, the results for only one industry, iron and steel foundries (SIC 332), are sketched here. Initially the industry is assumed to be in the steady state, which is generated by an output growth of 0.6 percent and a quit rate of 1.27 percent per month. These numbers are approximately equal to the average output growth and quit rate for Hamermesh's sample period. In the simulation the output growth then declines to −1.0 percent for a period of twelve months, after which it returns to its former level. The cumulative permanent reduction in output *below its initial growth path* is thus about 20 percent. The simulation has shown that, as a consequence of this assumed disturbance, employment must also fall *below its initial growth path* until the total reduction is about 8 percent. How is this reduction in employment brought about? The simulation provides the following answers: For every 1 percent reduction in employment (1) new hires fall by 0.93 points, (2) layoffs rise by 0.51 points, (3) rehires rise by 0.30 points and (4) other separations fall by 0.14 points.[11] Since quits are not allowed to vary, these numbers imply that *displacements account for 21 percent and unreplaced attritions for 79 percent of the net reduction in employment.*[12]

Thus the present analysis of the implications of Hamermesh's model for unreplaced attritions and displacements has led to the conclusion that unreplaced attritions may play a major role in bringing about reductions in employment. But this result depends crucially on the invariance of quits. What would happen if quits should fall with reductions in the demand for labor? In the next three sections an attempt is made to answer this question.

B. A Model with Endogenous Quits

In this section a labor turnover model is presented, which is similar in spirit to Hamermesh's but differs

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[9] The detailed results of this study of Hamermesh's model are contained in a working paper [4], which is available on request.

[10] Hamermesh did not construct his model with the aim of simulating it or of obtaining its implications for displacements and unreplaced attritions. Hence, he should not be held responsible for the methods or results of this part of the analysis.

[11] These figures are cumulated percentage deviations of the labor turnover flows from their initial steady-state levels.

[12] Displacements and unreplaced attritions are defined as $DIS = L - RH$ and $ATT = Q + D - NH$, where all variables are measured appropriately as cumulated deviations from their initial steady-state levels. But the estimates of DIS and ATT may contain biases because NH_1 has been omitted from both.

from it in crucial respects. In particular, the level of employment is now allowed to influence labor turnover and quits are no longer independent of conditions within the industry.

In the present framework, labor turnover actions are initiated by either employers or employees or caused by entirely autonomous factors such as military conscription, the compulsory retirement age, or ill health. Let us examine in turn the decision problems faced by employers and by employees.

(1) Employers are assumed to treat their voluntary quits and other separations as exogenous and to control their accessions (new hires plus rehires) and layoffs so as to bring about a net change in employment that is also endogenous and determined by the demand for the firm's output and similar conditions. Let us assume, for the present argument, that the employing unit is so small that all its employees are homogenous. The quantity $x_i = \Delta N_i + Q_i + D_i$ then measures the ith employer's deficiency of employees if $x_i > 0$ or surplus if $x_i < 0$. For such small employers it would not be optimal to *both* hire *and* lay off employees. Consequently when $x_i \geqslant 0$, then $A_i = x_i$ and $L_i = 0$; and when $x_i \leqslant 0$, then $L_i = -x_i$ and $A_i = 0$. The definition of x_i also implies that both A_i and L_i are related linearly to ΔN_i, Q_i and D_i, the former positively and the latter negatively. In contrast to this microtheoretic prediction that there should be *either* accessions or layoffs but not both, virtually all the available data on labor turnover show that both accessions and layoffs are quite large in all phases of the business cycle. This phenomenon is likely to be due to the fact that the data refer to more than one employing unit as defined above, so that employing units with both positive and negative x_i are aggregated. Let us, therefore, consider briefly how aggregation might affect the relationships among A, L, ΔN, Q, and D.

Let the x_i be distributed according to the discrete frequency function $f(x)$. Total industry layoffs, defined as a positive number, are then simply the sum of all negative x's, and similarly accessions are the sum of all positive x's:

$$L = \sum_{x=x_0}^{x=0} x f(x). \tag{16}$$

$$A = \sum_{x=0}^{x=x_1} x f(x) \tag{17}$$

where x_0 and x_1 are the lower and upper limits of the observed x's. The sum of all x's in the industry is denoted by X and can be expressed as

$$X = \sum_{x=x_0}^{x=x_1} x f(x) \tag{18}$$

It follows that $X = A - L$. Moreover, since $x_i = \Delta N_i + Q_i + D_i$ is a linear relationship, it can be aggregated so that $X = \Delta N + Q + D$ and, hence, $\Delta N = A - L - Q - D$, which is the basic identity expressed in equation (1).

Let us now consider the relationships between the aggregate variables X, A, and L. Suppose, for instance, that the x's for all micro units rise by an identical amount, so that the entire $f(x)$ distribution shifts to the right. Two effects of this shift can be distinguished: First, there are now *fewer* negative and *more* positive x's and, second, all the remaining negative and positive x's are higher than before. Both effects operate in the same direction. In aggregate, L must fall and both A and X must rise. Although the identity $\Delta N = A - L - Q - D$ must hold both before and after the rise in the x's, there is no reason to believe that the relationships between X and A or X and L are simple linear ones. Experimentation with even simple $f(x)$ functions tends to result in complex nonlinear aggregative relationships.

According to the above analysis, aggregate accessions and layoffs should both depend on aggregate ΔN, Q, and D, the former positively and the latter negatively. These predictions have been derived from the basic identity $x_i = \Delta N_i + Q_i + D_i$ and, as long as this identity holds exactly, all determinants of A and L must be reflected by ΔN, Q, and D, so that no additional factors can exert an influence on A and L. As has been mentioned in part 2, the time series data, which have been used in the empirical analysis, do not satisfy the identity exactly. In order to formalize this peculiarity of the data, let us introduce an error term Z, which brings about the identity *in the data*. In other words, Z is defined by $\Delta N = A - L - Q - D + Z$. The evidence of Table 1 suggests that Z is, on average, positive. With given ΔN, Q, and D it is now possible that A and L be influenced by additional factors that operate through Z. For instance, some determinant may raise both Z and L and leave ΔN, Q, and D unaffected. Since not much is known about the nature of Z, it is not easy to theorize about its determinants. At this stage it is only recognized that there may be determinants of A and L that are not reflected by ΔN, Q, and D but operate through Z.

So far, only total accessions and layoffs have been examined and nothing has been said about the determination of the components of accessions, namely new hires and rehires. Let us turn to this problem. Given that accessions A_i at the microeconomic level are positive, it seems plausible that employers first of all

rehire their previously laid-off but still available employees until their own stocks of laid-off employees SL_i are exhausted and only then, if indeed $A_i > SL_i$, do they hire new employees. The reason for this behavior is quite simple: SL may be viewed as a secondary work force from which employers can add to their employment stocks rapidly and at a relatively low cost of hiring, training, and phasing in. If, at the microeconomic level, employers are distributed over various SL_i (for $SL_i > 0$), then an aggregation argument similar to that used in the previous two paragraphs can be used to obtain the following aggregate prediction: At a given level of aggregate accessions A, a rise in aggregate SL should lead to a rise in aggregate rehires RH and a fall in aggregate new hires NH. Moreover, in aggregate, at a given level of SL, a rise in A should increase both NH and RH. The effect on RH should become weaker as A rises and more and more employers exhaust their own stocks of laid-off workers SL_i.

By way of summary, let us express the determination of aggregate new hires, rehires, and layoffs in formal terms:

$$NH = f_1\,(\overset{+}{\Delta N}, \overset{+}{Q}, \overset{+}{D}, \overset{-}{SL}), \tag{19}$$

$$RH = f_2\,(\overset{+}{\Delta N}, \overset{+}{Q}, \overset{+}{D}, \overset{+}{SL}), \tag{20}$$

$$L \;\; = f_3\,(\overset{-}{\Delta N}, \overset{-}{Q}, \overset{-}{D}, SL), \tag{21}$$

where the signs above the variables indicate the direction of their theoretically expected influence upon NH, RH, and L. For the sake of generality, SL has been included also in the layoff equation. This can be justified only on the grounds that SL is a determinant of the error term Z, but no sign prediction can be made. Equations (19) to (21) can also be rearranged to yield expressions for the two variables that are of primary interest, displacements and unreplaced attritions:[13]

$$DIS = L - RH = f_4\,(\overset{-}{\Delta N}, \overset{-}{Q}, \overset{-}{D}, \overset{-}{SL}), \tag{22}$$

$$ATT = Q + D - NH = f_5\,(\overset{-}{\Delta N}, Q, D, \overset{+}{SL}). \tag{23}$$

As mentioned, employers are envisaged, within the present framework, to regard their quits and other separations as exogenous and to take a *joint* decision on new hires, rehires, layoffs, and the net change in employment. Having discussed the determination of new hires, rehires, and layoffs, let us now turn to a description of the *net* demand for labor. There exists an extensive literature on net employment functions. The particular version of employment function proposed here is similar to the one derived by Brechling and Mortensen [5], Brechling [3], and Nadiri and Rosen [13]. It is part of a multivariate stock adjustment model in which employment N, real inventories I, and unfilled orders U are determined. The comparative static levels N^*, I^*, and U^* are determined, through a cost minimization procedure, by real orders OR, the real wage rate w, technological change represented by a time trend t, quits Q, other separations D, and the stock of laid-off workers SL. The net employment function can be written formally as:

$$\Delta N = \overset{+}{m_1}\,(N_t{}^* - N_{t-1}) + \overset{+}{m_2}\,(I_t{}^* - I_{t-1}) \tag{24}$$

$$+ \overset{-}{m_3}\,(U_t{}^* - U_{t-1}),$$

$$N_t{}^* = g_1\,(\overset{+}{OR}, \overset{-}{w}, \overset{-}{t}, \overset{+}{Q}, \overset{+}{D}, \overset{-}{SL}), \tag{25}$$

$$I_t{}^* = g_2\,(\overset{+}{OR}, \overset{+}{w}, \overset{-}{t}, Q, D, SL), \tag{26}$$

$$U_t{}^* = g_3\,(\overset{+}{OR}, \overset{+}{w}, \overset{-}{t}, Q, D, SL). \tag{27}$$

As before, the signs over the coefficients or variables indicate the plausible directions of the influences of the exogenous variables. Most, but not all, of these signs are implied unambiguously by the theory, as is shown in the studies cited. The influence of Q, D, and SL upon N^* requires special comment. As Q and D rise with constant real orders, employees have to be replaced more frequently; this implies a rise in the cost of labor and hence, a tendency for N^* to fall. But the rise in Q and D also implies an increase in the proportion of employees who are being trained and phased in at any time and thus a reduction in the average level of training of the employees and this effect tends to raise N^*. In equation (25) the second effect is assumed to dominate. The negative influence of SL upon N^* is based on a proposition put forward by Barth [2]: If firms regard SL as a kind of secondary labor force that is used as a buffer in cyclical adjustments, then a rise in SL reduces the probability that this buffer will be exhausted, and consequently firms reduce their comparative static employment levels N^*.

It should perhaps be emphasized that equation (24) is only one of three dynamically interdependent equations. The other two relate ΔI and ΔU to the same independent variables through related parameters. The

[13] As has been pointed out in part 2 of this paper, these expressions for DIS and ATT are only approximately correct: DIS includes but should exclude NH_1, and ATT excludes but should include it. Typically DIS must be expected to be too high and ATT too low. No attempt has been made to estimate empirically the other displacement concept, namely $DIS_1 = L - \Delta SL - RH$ and, hence, it is not dealt with explicitly in this part of the paper.

omission of these two equations means that the individual parameters of equations (25) to (27) cannot be identified and hence the sign predictions discussed above cannot be tested. Further, the omission of the equations for ΔI and ΔU requires some special assumptions in the simulation exercise reported in section D.

(2) Having described employer's behavior, let us turn to a discussion of the remaining two labor turnover categories, quits Q and other separations D. Quits are initiated by employees whose decision to quit their present positions depends on their quit propensities and the attractiveness of their present positions in relation to alternatives. In particular, the absolute level of quits in an industry is assumed to depend on the following seven factors. First, the initial total level of employment N_{t-1} should have a positive effect on quits Q_t which, however, need not be equiproportionate. Second, the industry's wage in relation to the mean wage in all other industries w/w_o should have a negative influence on Q_t. Third, the industry's employment growth ΔN should affect quits negatively. A rise in ΔN is expected to imply a reduction in the probability of being laid off and, hence, to make jobs within the industry more attractive. Fourth, a rise in the employment growth of all other industries ΔE should make alternative industries relatively more attractive and raise quits. Fifth, the number of low-tenure employees in the industry is expected to have a positive effect on total industry quits. The reason for this effect is that low-tenure employees tend to have very high quit propensities, a phenomenon consistent with the theoretical argument that employees learn about the nonpecuniary aspects of their jobs at low tenure levels and quit when they find them unattractive. Unfortunately, no series of the tenure distributions of employees are published for the current sample of industries. Consequently, of various proxy variables considered, it was decided to use the recent growth in employment. In particular, Wi is defined as the growth in employment over the past i quarters prior to the beginning of the current quarter: $Wi = N_{t-1} - N_{t-1-i}$, which is expected to have a positive impact on total quits. The *current* employment change ΔN might, however, also be a good indicator of the numbers of low-tenure employees and thus exert a positive effect on quits. This positive effect might outweigh the negative effect of ΔN discussed above. Sixth, the stock of laid-off workers SL_{t-1} at the beginning of the quarter may also have a negative influence on quits. A rise in SL_{t-1} should discourage those quitters who normally find new jobs within the *same* industry because SL_{t-1} is a measure of job availability within the industry. Seventh, in order to represent any omitted variables, a time trend t was also allowed to play a role in the determination of total quits. In formal terms, the proposed quit function can, therefore, be written as

$$Q_t = f_4\,(N_{t-1}, \Delta N, \Delta E, (w/w_o)_t, Wi_t, SL_{t-1}, t), \quad (28)$$

which seems consistent with theoretical models of quits, for instance, with Parsons' model [15], which is based on a search-theoretic framework. In contrast to some previous specifications of quit functions, for instance Hamermesh's [8], equation (28) does not contain the national unemployment rate. Both a priori considerations and experimentation with different variables suggested that ΔN, ΔE, and SL_{t-1} may be the best set of explanatory variables to represent job opportunities inside and outside the industry.

The other separations D consist of several components that may be influenced by different factors and, hence, it is rather difficult to model them satisfactorily. It would appear, however, that at least some of the arguments in the quit function should also play a role in the determination of other separations. Thus the variables that measure the relative attractiveness of jobs in the industry may influence retirements to the extent that they are not completely automatic. Further, the Wi variable may again be an adequate measure of the number of low-tenure employees, which must be an important determinant of the number of discharges for reasons such as incompetence or dishonesty. Finally, N_{t-1} should again be included as a scale variable that may influence D_t nonproportionately. Thus the last turnover function can be expressed formally as

$$D_t = f_5\,(N_{t-1}, \Delta N, \Delta E, (w/w_o)_t, Wi_t, SL_{t-1}, t). \quad (29)$$

Equations (19) to (29) describe two versions of the model of net and gross flows of labor that have been used in the empirical estimation in the attempt to obtain empirical measures of displacements and unreplaced attritions. In the first version of the model, equations (22) and (23) are omitted so that the employers' turnover variables are NH, RH, and L, whereas in the second version equations (19) to (21) are omitted so that the employers' turnover variables are DIS and ATT. The remainder of the model is identical in both versions. Further, for some purposes the model has to be supplemented by equation (10), which describes the movement of SL through time. In both versions of the *complete model*, the following variables are thus endogenous: ΔN and, hence, N_t, Q, D, and ΔSL and, hence, SL_t. In addition, NH, RH, and L are endogenous in the first and DIS and ATT in the second version of the model. Further, the following variables are *exogenous* in both versions of the complete model: OR, w, t, N_{t-1}, I_{t-1}, U_{t-1}, SL_{t-1}, w/w_o, ΔE, Wi, and δ.

Let us now turn to a description of the estimation of this model.

C. The Empirical Results

The model that is summarized by equations (19) to (29) has been fitted to quarterly data for twenty-four manufacturing industries. Most of the data required for this purpose are readily available in *Employment and Earnings, Manufacturers' Sales, Inventories and Orders*, and the *Monthly Labor Review*. Some data had to be processed prior to fitting the model. The raw data have, however, not been seasonally adjusted and, hence, intercept dummies for the second, third, and fourth quarters have been included as independent variables. Typically these dummies take on the value 1 in their own quarter and 0 in others. In the equations for quits and other separations, however, the seasonal pattern was found to be slightly different and the dummies take on the value of N_{t-1} in their own quarter and 0 in all others.

In initial trials the net labor demand and labor turnover functions were approximated by both linear and log-linear forms. By and large, the linear versions of the model tended to give better results. The linear specification also has the advantage that the constraint given by $\Delta N = A - S$ can be checked or incorporated into the model quite easily.

Various alternative estimaton methods have been used, but the differences in the results do not seem to be substantial. For the results presented here, the net demand for labor, the quit, and the other separations functions have been estimated by ordinary least-squares and all the other labor turnover functions by two-stage least-squares for which ΔN is the jointly dependent variable.

For some equations the Durbin-Watson statistics are somewhat low. These equations were adjusted for autocorrelation and reestimated. Since, however, the regression coefficients did not change very much, only the results of the unadjusted equations are reported. Low Durbin-Watson statistics should thus be regarded as signals pointing to possible misspecifications.

For brevity the results for only two industrial categories, total durable and total nondurable goods industries, are presented but some of the other results are mentioned briefly. The evidence of Table 2 suggests that the net flow demand for labor is determined predominantly by real orders, the time trend, quits, and lagged employment. In durable goods industries unfilled orders also appear to exert a positive influence upon ΔN. The real wage and the stock of laid-off workers do not affect the net change in employment significantly.

Table 2
The Net Employment Demand Equations

Independent Variables	Durables	Nondurables
OR	0.0262	0.0330
	(5.08)	(4.26)
w	−29.085	101.89
	(−0.07)	(0.64)
t	−10.043	−12.418
	(−2.28)	(−4.77)
Q	0.6996	0.2480
	(2.39)	(1.84)
D	1.3649	0.7459
	(1.28)	(1.54)
SL	−0.0871	0.2021
	(−0.41)	(0.76)
N_{t-1}	−0.7429	−0.2181
	(−3.95)	(−2.02)
I_{t-1}	0.0193	−0.0244
	(1.11)	(−1.31)
U_{t-1}	0.0124	−0.0074
	(1.86)	(−0.21)
R^2	0.79	0.93
D-W	1.21	2.23

Note: The figures in parentheses are t-ratios. For sample periods, see Table 1. The column headed D-W contains the Durbin-Watson d-statistics.

Table 3 contains the empirical estimates of the parameters for the new hire, rehire, layoff, and displacement equations. In all of these equations, ΔN is treated as the jointly dependent variable, so that the values for $\Delta\hat{N}$ are those predicted by the instrumental variables that are the independent variables listed in Table 2. Let us discuss the parameters in Table 3 in some detail. New hires are affected positively and significantly by the net change in employment and quits and negatively by the stock of laid-off employees. Rehires are related positively to the stock of laid-off workers but not very strongly or consistently to any of the other variables. Layoffs respond negatively to net employment changes, quits, and other separations and positively to the stock of laid-off employees. As has already been pointed out, this positive association between L and SL must be attributed to a positive association between the error Z and SL. In other words, as the stock of laid-off employees rises, the error Z, which is defined by $\Delta N = A - L - Q - D + Z$, tends to rise and this rise is offset by an increase in L. This is an interesting association, which deserves further analysis and may yield a clue to the reason why Z occurs. Next let us consider displacements. Two series for displacement have been fitted. Series A is defined as $DISA = L - RH$ and series B as $DISB = L - RH - Z$.

Table 3

The New Hire, Rehire, Layoff, and Displacement Equations

Independent Variables	New Hires	Rehires	Layoffs	Displacements *A*	Displacements *B*
			Durables		
$\widehat{\Delta N}$	0.3984 (8.95)	−0.1101 (−3.47)	−0.7310 (−13.94)	−0.6210 (−13.22)	−0.6016 (−13.51)
Q	0.9210 (8.93)	0.0786 (1.07)	0.0985 (0.81)	0.0200 (0.18)	−0.0790 (−0.77)
D	−0.1192 (−0.42)	0.1885 (0.95)	−0.7579 (−2.27)	−0.9463 (−3.17)	−1.1192 (−3.96)
SL	−0.2589 (−5.52)	0.3085 (9.23)	0.1739 (3.15)	−0.1346 (−2.72)	−0.2589 (−5.52)
R^2	0.97	0.87	0.88	0.89	0.91
D-W	2.06	1.22	2.19	2.27	2.06
			Nondurables		
$\widehat{\Delta N}$	0.4037 (4.87)	0.0105 (0.24)	−0.5929 (−10.49)	−0.6034 (−9.38)	−0.5963 (−7.19)
Q	0.8254 (11.13)	−0.0125 (−0.32)	−0.1576 (−3.12)	−0.1450 (−2.52)	−0.1746 (−2.35)
D	0.2952 (1.20)	−0.1893 (−1.45)	−0.4352 (−2.59)	−0.2459 (−1.29)	−0.7048 (−2.86)
SL	−0.1900 (−1.69)	0.1855 (3.10)	0.1721 (2.24)	−0.0134 (−0.15)	−0.1900 (−1.69)
R^2	0.98	0.91	0.95	0.95	0.95
D-W	1.11	1.09	1.83	1.82	1.11

For notes, see Table 2.

Corresponding to these two series there are two series for unreplaced attritions; series A includes and series B excludes Z, or $ATTA = Q+D-NH-Z$ and $ATTB = Q+D-NH$. As a result of these definitions, the error Z is attributed to either DIS or ATT, so that the definitional identity between the net and gross flows of labor has been made to hold exactly in these data. In other words, $ATTA + DISA = -\Delta N$ and $ATTB + DISB = -\Delta N$ and either the A or the B specification can be used. The coefficients that relate $ATTA$ and $ATTB$ to $\widehat{\Delta N}$, Q, D, and SL can be obtained easily from the coefficients of the displacement equations in Table 3. The $\widehat{\Delta N}$ coefficients of the displacement and attrition equations must sum to −1 and the coefficients of Q, D, and SL have the same absolute value but opposite signs in the displacement and attrition equations.[14] As it happens, the $DISA$ and $DISB$ equations are quite similar, but the B specification, which assigns the error Z to displacements, seems slightly superior to the A specification. By and large, the results for the other twenty-two industries are similar to those presented in Table 3. In particular, new hires tend to be related positively and layoffs negatively to $\widehat{\Delta N}$, Q, and D. Further, increases in SL tend to raise new hires and reduce rehires. But other aspects of the rehire equations are not entirely satisfactory.

Table 4 contains the final set of results, namely those for quits and other separations. Both quits and other separations are related positively to the level of employment N_{t-1} and the current and recent changes in employment ΔN and $W4$. Further the impact of relative wage w/w_0 is negative but not significant. The time trend tends to have a positive influence on quits and a negative one on other separations. The stock of laid-off workers raises quits in durables and reduces them in nondurables, whereas the change in employment outside the industry ΔE reduces quits in durables and raises

[14]Thus the coefficients of the $ATTA$ equation for total durables are −0.3790, −0.0200, 0.9463 and 0.1346 for $\widehat{\Delta N}$, Q, D, and SL, respectively. It should be noted that $DISB$ can also be expressed as $DISB = -\Delta N+NH-Q-D$ and, hence, the coefficients of the NH and $DISB$ equations are related.

Table 4
The Quit and Other Separations Equations

Independent Variables	Durables Quits	Durables Other Separations	Nondurables Quits	Nondurables Other Separations
ΔN	0.2941 (6.63)	0.0486 (3.29)	0.0188 (0.19)	0.0287 (0.87)
N	0.2642 (10.75)	0.0578 (7.06)	0.3677 (5.56)	0.0688 (3.19)
t	−3.5610 (−5.30)	0.1607 (0.72)	−0.3372 (−0.44)	0.7831 (3.13)
SL	0.1537 (2.29)	0.0043 (0.19)	−0.1996 (−1.16)	0.0133 (0.24)
w/w_o	−506.09 (−0.68)	−334.18 (−1.34)	−922.21 (−0.68)	−508.03 (−1.15)
$W4$	0.0848 (3.75)	0.0044 (0.59)	0.1071 (2.09)	0.0152 (0.91)
ΔE	−0.1965 (−2.26)	−0.0240 (−0.83)	0.1092 (3.06)	−0.0029 (−0.25)
R^2	0.97	0.96	0.97	0.91
$D\text{-}W$	1.76	1.35	1.48	1.76

For notes, see Table 2.

them in nondurables. The results from the other twenty-two industries seem to contain very similar messages: ΔN, N_{t-1}, and $W4$ influence quits and other separations predominantly positively. But the strongest result is that for the relative wages w/w_o: In twenty of the remaining industries the coefficient of w/w_o is negative and in thirteen it is significantly so. This is an encouragingly strong result, especially in view of difficulties that are often encountered in attempts to discover the effects of relative prices in time series analyses.

It is not claimed that the empirical estimates presented in Tables 2 to 4 are entirely satisfactory. Several of the parameters have implausible signs and others are not significant. But this evidence does contain some substantive information on the interrelationships between net and gross flows of labor. These interrelations will be analyzed further in the next section.

D. The Simulation

The model summarized in equations (19) to (29) has several complex dynamic interdependencies and, hence, it is difficult to ascertain all its properties by analytical methods. An attempt has, therefore, been made to obtain the most important implications of the model by means of a simulation exercise. Let us describe this simulation in some detail by dealing, first, with the steady-state properties of the model and, second, with its short-run responses to exogenous shocks.

(1) For a discussion of the steady-state properties of the model, equations (19) to (29) have to be supplemented by equation (10), which describes the movement through time of the stock of laid-off employees. The steady state of the model is then said to exist when $\Delta N = N_t - N_{t-1} = 0$, $Wi = N_{t-1} - N_{t-1-i} = 0$, and $\Delta SL = SL_t - SL_{t-1} = 0$. In other words, with given exogenous variables, all endogenous variables are at their steady-state levels when *both* the stock of employment *and* the stock of laid-off employees are constant over time. When these steady-state conditions are assumed, the model, with the estimated parameters, can be solved for its endogenous variables on the basis of any arbitrary set of exogenous variables. For the initial computations, the exogenous variables OR, w, t, l_{t-1}, w/w_o, ΔE, and δ were assumed to be at their sample means. The resulting steady-state values of the endogenous variables are presented in Table 5, together with their sample means. For version 2 of the model the error Z has been attributed to displacements and therefore $DISB + ATTB = -\Delta N$.

Inspection of the figures in Table 5 suggests that the steady-state values of the endogenous variables are not vastly different from their sample means. This similarity is not necessarily implied by the structure of the model or the estimation techniques and, hence, it may be viewed as a satisfactory aspect of the model.

In order to be able to study the response of the model to an exogenous reduction in demand, the system was

Table 5
The Steady-State Values of the Endogenous Variables

	Durables			Nondurables		
		Steady-State Values			Steady-State Values	
	Sample Means	Version I	Version II	Sample Means	Version I	Version II
ΔN	16.695	0	0	11.642	0	0
N	10705.281	10719.087	10709.419	7749.955	7861.774	7757.818
SL	518.142	555.540	383.676	257.607	255.530	211.250
NH	868.019	848.157		761.760	787.815	
RH	400.792	413.798		316.676	313.976	
L	478.545	497.129		396.342	393.191	
Q	562.095	558.222	529.140	533.014	567.951	536.617
D	281.003	280.663	279.340	167.287	173.886	165.907
$DISB$	8.226		57.551	49.818		65.488
$ATTB$	−24.921		−57.551	−61.460		−65.488
$NH+RH-L-Q-D$	−52.832	−74.059		−18.207	−33.237	
$L-RH$	77.753	83.331		79.666	79.215	
$Q+D-NH$	−24.921	−9.272		−61.459	−45.978	
Z	69.527	74.059	0	29.849	33.237	0

Note: All numbers in thousands. For sample periods, see Table 1. Version I consists of equations (10), (19) to (21) and (24) to (29). Version II consists of equations (10), (22), (23) and (24) to (29). Z is defined as $Z = \Delta N - NH - RH + L + Q + D = \Delta N + ATT + DIS$.

started in the initial steady state and then subjected to an exogenous shock that took the form of a 10 percent reduction in real orders OR, real inventories I, and real unfilled orders U. But the other exogenous variables were all held at their sample means. This procedure may require some further explanation.[15] As has been mentioned in section B of this part of the paper, the model expressed in equations (19) to (29) should be supplemented by two additional dynamically interdependent functions; they determine the change in real inventories ΔI and in real unfilled orders ΔU. In a complete specification of the dynamic effects of changes in demand, firms should be allowed to respond to a ceteris paribus reduction in real orders OR by reducing gradually the stocks of equipment, real inventories, and real unfilled orders to their new steady-state levels. In the present simulation, by contrast, real inventories and unfilled orders are reduced to their new steady-state levels *instantaneously* and, moreover, these reductions are supposed to be proportionate to that in real orders. Thus, the simulation traces the short-run and long-run effects of a 10 percent reduction in real orders, real inventories, and real unfilled orders upon net employment and all the labor turnover categories. The reason for this simplified approach is that the primary purpose of the research underlying this paper has been to obtain the relationships between net changes in employment and the labor turnover flows. The estimates of these relationships may not be affected much by the above simplification, which seems to influence primarily the estimate of the net change in employment.

The long-run effects of a 10 percent reduction in OR, I, and U are presented in Table 6. This table contains the new steady-state levels of the endogenous variables for the two versions of the model and the two industry groups as well as the percentage differences between the initial and the new steady-state levels. Thus, the reductions in OR, I, and U cause reductions in the steady-state values of employment, new hires, quits, other separations, and unreplaced attritions and increases in those of the stock of laid-off employees, rehires, layoffs and displacements. The signs of the changes in the steady-state levels are the same for both industry groups though their magnitudes differ substantially in some instances. A particularly striking feature of these numbers is the large decline in quits, which is much larger proportionately than that in employment. Consequently, the quit *rate*, that is, the ratio of Q to N, is much lower in the depressed than in the prosperous steady state.

A comparison of the steady-state levels in Tables 5 and 6 suggests that, in relatively prosperous times, quits, other separations, and new hires tend to be high

[15] If the reduction in an industry's output is due to a trade liberalization policy that involves international reciprocity, then the simulation exercise should be based on the assumption that some industries contract and others expand their employment levels. In the above simulation alternative industries remain unaffected and, hence, the present results may be too gloomy.

Table 6
The Second Steady-State Values

	Durables				Nondurables			
	Version I		Version II		Version I		Version II	
	New Level	Percent Difference*	New Level	Percent Difference	New Level	Percent Difference	New Level	Percent Difference
N	10004.447	−6.67	9995.944	−6.66	6721.538	−14.50	6618.925	−14.68
SL	683.323	23.00	532.159	38.70	537.127	110.20	493.418	133.57
NH	657.045	−22.53			301.416	−61.74		
RH	431.364	4.25			387.062	23.28		
L	533.863	7.39			553.571	40.79		
Q	381.189	−31.71	355.610	−32.79	71.139	−87.47	40.210	−92.51
D	238.496	−15.02	237.332	−15.04	96.575	−44.46	88.699	−46.54
DISB			79.824	38.70			152.960	133.57
ATTB			−79.824	−38.70			−152.960	−133.57
$NH+RH-L-Q-D$	−65.139	12.04			−32.807	1.29		
$L-RH$	102.499	23.00			166.509	110.20		
$Q+D-NH$	−37.360	−302.93			−133.702	−190.80		

For notes, see Table 5.
*The differences in the steady-state levels in Tables 5 and 6.

and to take care of a relatively large proportion of the reallocation of workers among establishments and industries. In relatively depressed times, on the other hand, quits, other separations, and new hires tend to be low and the function of the reallocation of workers seems to be shifted to layoffs, rehires, and the stock of laid-off employees, all of which are larger than in prosperous times.

(2) Although the long-run consequences of reductions in real orders, inventories, and unfilled orders may be of considerable interest, the primary focus of the research underlying the present paper is on the short-run adjustment paths of employment and the labor turnover flows. Figures 2 to 5 trace the paths of employment, the stock of laid-off employees, and the turnover variables that occur as a consequence of the 10 percent exogenous reduction in real orders, inventories, and unfilled orders. The figures refer to both versions of the model and both industry groups. The reader should note that the scales of Figures 2 to 5 are not all identical and that the origin of the stock of employment has been adjusted so as to make it fit into the diagrams with the other variables. The main implications of Figures 2 to 5 are as follows: all four versions of the model are stable in the sense that the variables approach their new steady-state levels and do not diverge from them. Further, in the durable goods industries, adjustment tends to be quite fast: all variables are quite close to their new steady states within one year after the disturbance. In the nondurable goods industries the adjustment is somewhat slower. Further, in nondurables the variables approach their new steady-state levels monotonically, whereas in durables they overshoot their steady-state levels and then return to them.

In order to obtain an impression of the roles played by the various labor turnover categories in a downward adjustment of employment, Table 7 has been prepared. It contains the cumulated deviations from the initial steady states of the various net and gross flows of labor. The period over which the observations have been cumulated is one calendar year, namely the four quarters that follow the exogenous demand reduction. Thus, the number in the first row and column in Table 7 indicates that, during the four quarters after the disturbance, employment has fallen by a total of 709,800 below its initial steady-state level and the other numbers in the first column should be interpreted similarly. To obtain an impression of the *relative* importance of the various labor turnover categories, the numbers are presented also as percentages of $-\Delta N$. The following characteristics of the evidence in Table 7 should be noted. In version 1 of the model new hires decline by more than the net reduction in employment in both industry groups. But this decline is offset by substantial reductions in quits and other separations, so that the estimated unreplaced attritions are only 15.6 percent of $-\Delta N$ in durables and -13.5 percent in nondurables. Layoffs rise substantially and are offset only partially by increases in rehires so that the estimated displacements are 57.2 and 69.5 percent of $-\Delta N$ for durables and nondurables, respectively. The error, that is the difference between ΔN and $(NH+RH-L-Q-D)$ is 27.2 percent for durables and 44 percent for nondura-

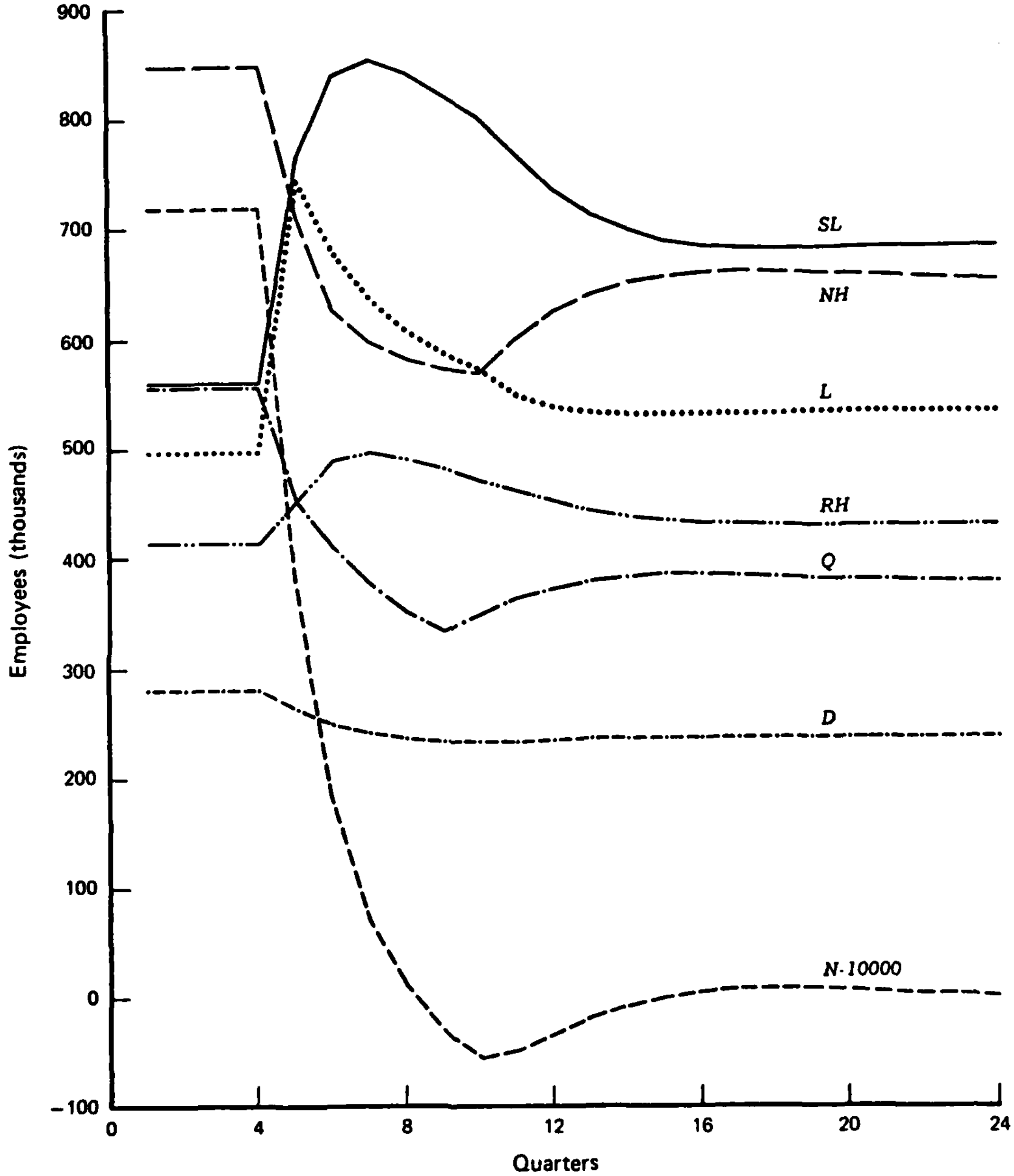

Figure 2
Durable Goods Industries, Version 1

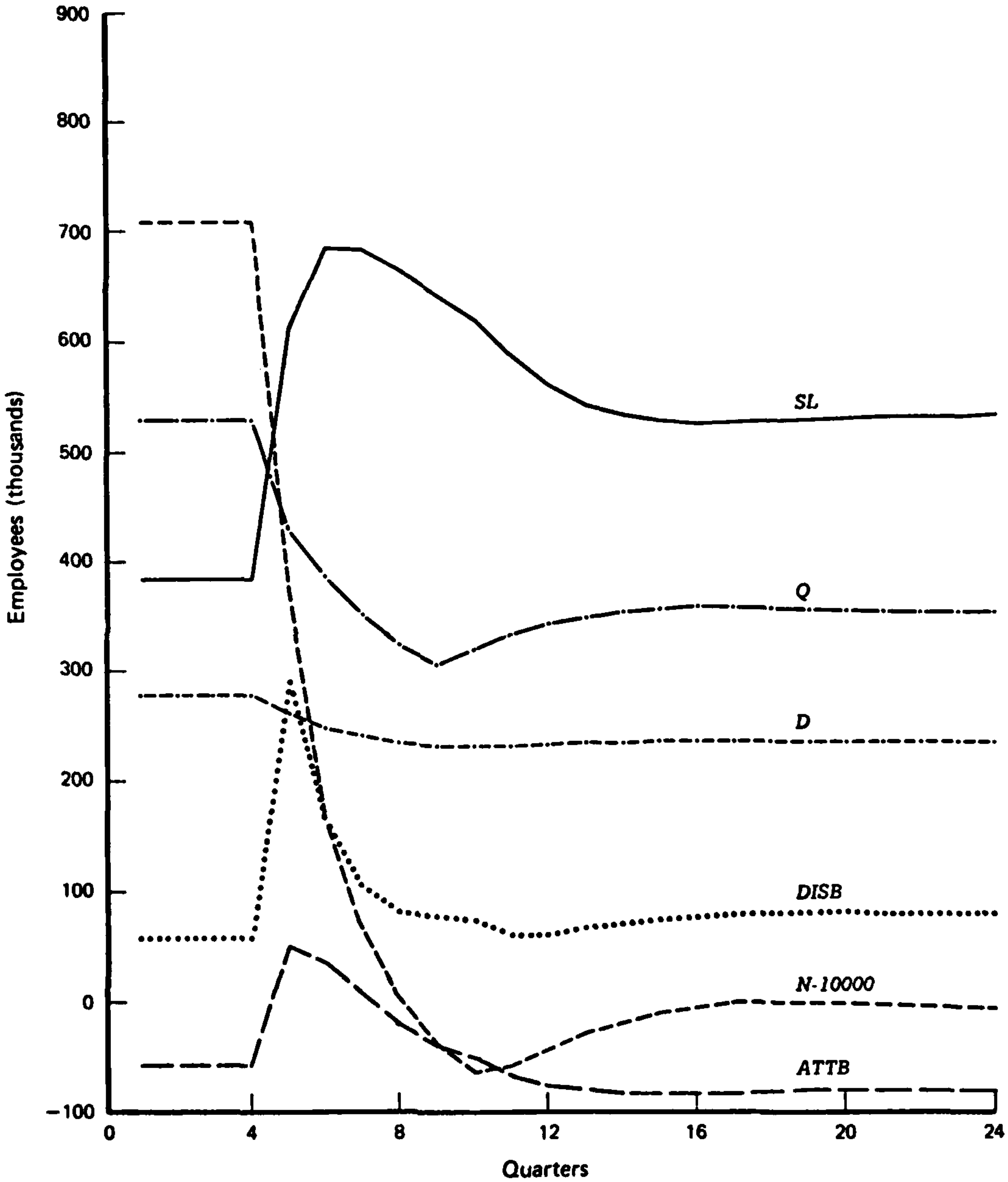

Figure 3
Durable Goods Industries, Version 2

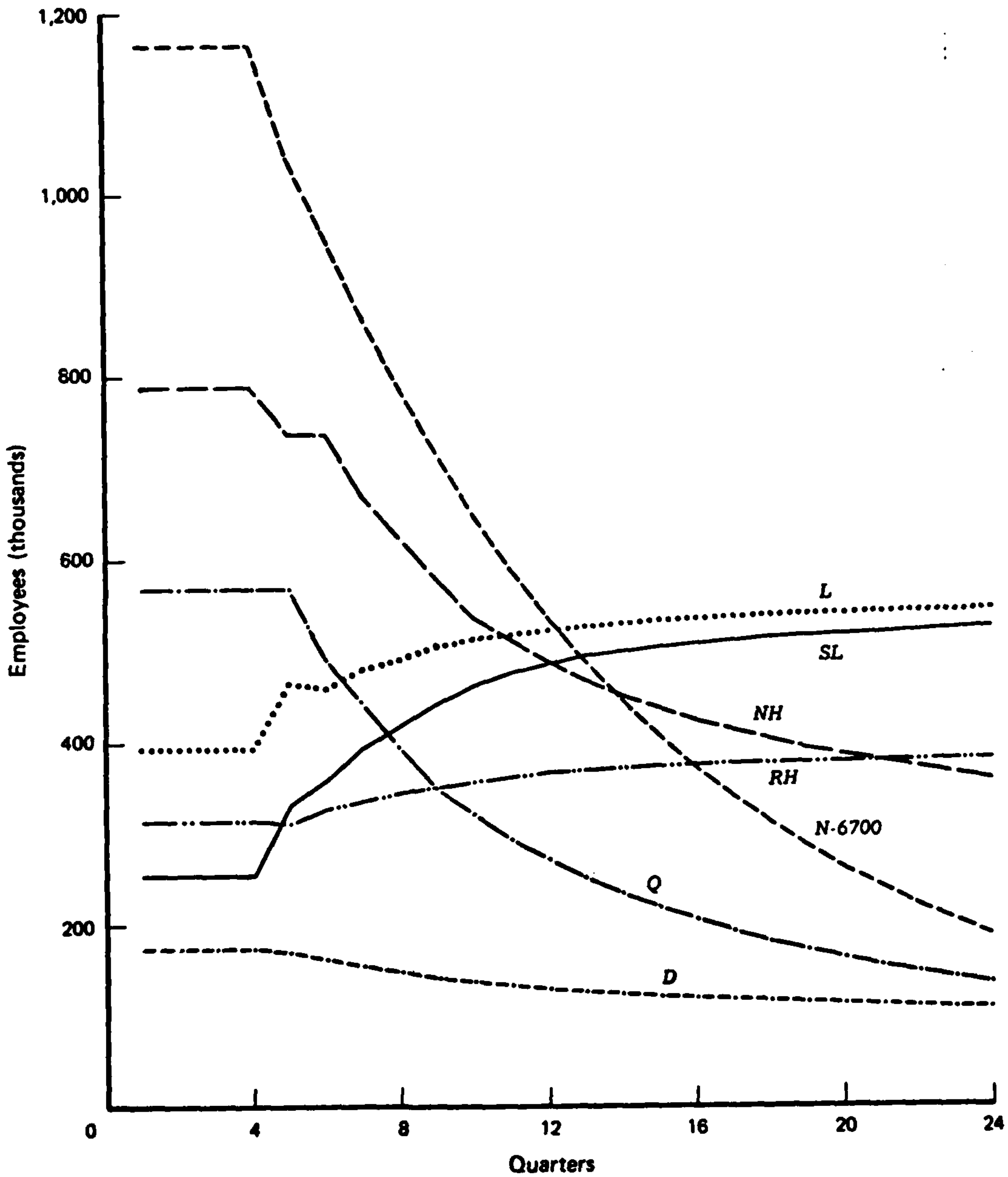

Figure 4
Nondurable Goods Industries, Version 1

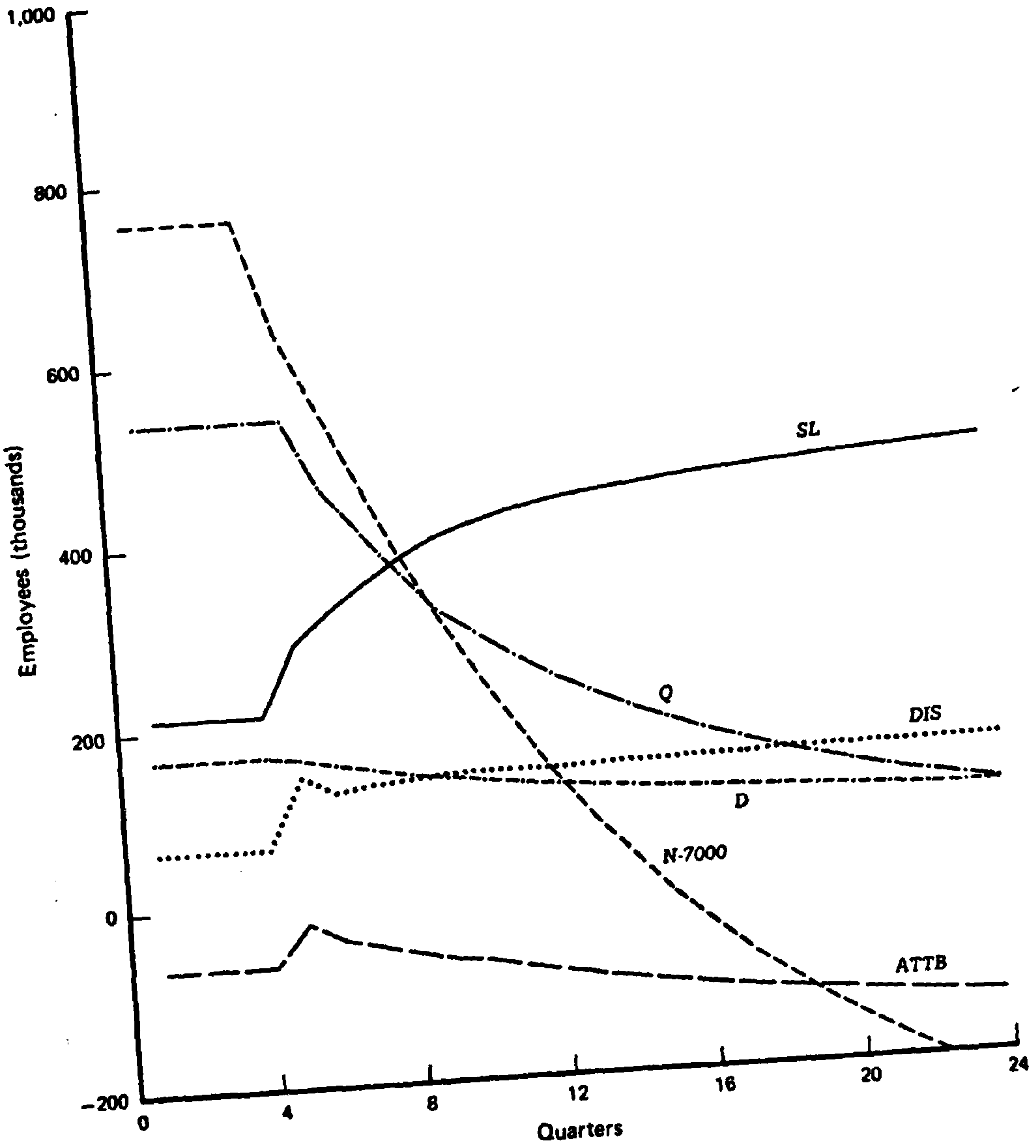

Figure 5
Nondurable Goods Industries, Version 2

Table 7

Cumulated Deviations from Initial Steady States

	Durables				Nondurables			
	Version I		Version II		Version I		Version II	
	Thousands	Percent of $-\Delta N$	Thousands	Percent of $-\Delta N$	Thousands	Percent of $-\Delta N$	Thousands	Percent of $-\Delta N$
ΔN	−709.8	100.0	−708.3	100.0	−374.6	100.0	−372.2	100.0
NH	−873.1	−123.0			−392.1	−104.7		
RH	273.8	38.6			63.8	17.0		
L	679.7	95.8			324.2	86.6		
Q	−633.6	−89.3	−628.3	−88.7	−381.7	−101.9	−383.6	−103.1
D	−128.7	−18.1	−128.5	−18.2	−61.1	−16.3	−60.6	−16.3
$L-RH$	405.9	57.2			260.4	69.5		
$Q+D-NH$	110.8	15.6			−50.7	−13.5		
$NH+RH-L-Q-D$	−516.7	−72.8			−209.7	−56.0		
$DISB$			404.4	57.1			268.7	72.2
$ATTB$			303.9	42.9			103.5	27.8

bles. In version 2 of the model this error must disappear. The differences between the estimates of ΔN, Q, and DIS for the two versions of the model are negligibly small. The only striking differences occur in the estimates of unreplaced attritions, which are substantially higher in version 2 than in version 1. Indeed, the entire error of version 1 seems to be attributed to $ATTB$ in version 2.

For present purposes, the most interesting implication of Table 7 is that, despite the very large decline in new hires, unreplaced attritions seem to play only a secondary role in bringing about net reductions in employment. The reason for this phenomenon is that new hires respond to a sharp fall in quits so that new hires and quits fall in a mutually offsetting manner. In section 3A, it has been pointed out that Hamermesh's approach implies that unreplaced attritions account for 79 percent of any net reduction in employment. As noted, this finding is based on the assumption that the industry's quit rate is independent of economic conditions within the industry. The finding of the present research is that such an assumption can substantially bias the results. The numbers in Table 7 suggest, by contrast to Hamermesh's, that the fall in quits may prevent unreplaced attritions from bringing about a large proportion of any net reduction in employment. According to these estimates unreplaced attritions amount to, at most, 42.9 percent of $-\Delta N$. Although no finality is claimed for the present results, they do suggest that quits ought to be allowed to respond to changes in economic conditions within the industry in future investigations of labor turnover, especially if they are aimed at obtaining estimates of unreplaced attritions and displacements.

4. Conclusions

In the research underlying this paper an attempt has been made to estimate the displacements and unreplaced attritions that must be expected to occur as a result of exogenous reductions in the demand for an industry's output. Such reductions may be caused by many factors, including trade liberalization measures and the ensuing increase in import penetration, the effects of which are of particular interest in the present context.

Parts 2 and 3 of this paper contain the general conceptual framework of the analysis, a description of the time series data, and the result of the construction, estimation, and simulation of the model. The main conclusion of the analysis is that unreplaced attritions may not be as important in bringing about net reductions in employment as is sometimes suggested. Although firms cut their new hires drastically when demand falls, this is largely caused and offset by substantial reductions in voluntary quits. In other words, since attritions fall with demand conditions, attempts by firms to effect net reductions in employment through unreplaced attritions tend to have only limited success and the primary method of reducing employment takes the form of displacements.

It seems that the time series data on labor turnover have not been analyzed previously with a view to obtaining estimates of displacements and unreplaced attritions. The estimates presented in this paper should, therefore, be regarded as a first attempt at generating quantitative information that has potentially important implications for economic policy. A number of obvious

areas for further research suggest themselves. The conceptual framework might be changed. Following Mortensen [17] and Pencavel [12], it might be assumed that the typical firm controls its quits through its relative wages. The rehire equation, which currently yields unsatisfactory empirical results, should perhaps also be specified differently. For the empirical estimation, different functional forms and different econometric methods could be tried in an effort to improve the results. Finally, estimates of displacements and unreplaced attritions should be obtained for industries that are smaller than total durable and total nondurable goods industries. Disaggregation seems to be especially desirable, because at highly aggregated industry classifications much labor turnover is intra-industry turnover and, as has been pointed out in part 2 of this paper, such intra-industry turnover, to the extent that $NH_t > 0$, tends to bias the estimates of displacements and unreplaced attritions. As discussed in part 3, the model has been fitted to twenty-two additional manufacturing industries and the results are being analyzed currently. As has been found by Nadiri and Rosen [13], however, the same model of factor demand does not perform equally well at all levels of aggregation and, hence, some industry-specific modeling may be necessary. It is hoped that future research will provide information on the reliability of the currently available estimates of displacements and unreplaced attritions as well as on the source of any intra-industry differences in the relative importance of displacements and unreplaced attritions as a means of reducing employment.

Literature Cited

1. Bale, Malcolm D. "Estimates of Trade-Displacement Costs for U.S. Workers." *Journal of International Economics*, 6 (August 1976), 245–50.
2. Barth, Peter S. "A Time Series Analysis of Layoff Rates." *The Journal of Human Resources*, 6 (Fall 1971), 448–65.
3. Brechling, Frank. "Hamermesh's Labor Turnover Model and Its Implications for Displacements and Attritions." Mimeographed. PRI Working Paper 76-306.
4. ______. *Investment and Employment Decisions*. Manchester: Manchester University Press, 1975.
5. Brechling, Frank, and Dale Mortensen. "Interrelated Factor Demand Functions." Mimeographed.
6. Burton, John F., and John E. Parker. "Interindustry Variations in Voluntary Labor Mobility." *Industrial and Labor Relations Review*, 22 (January 1969), 199–216.
7. Hall, Robert E. "Turnover in the Labor Force." *Brookings Papers on Economic Activity*, (3: 1972), 709–53.
8. Hamermesh, Daniel S. "A Disaggregative Econometric Model of Gross Changes in Employment." *Yale Economic Essays*, 9 (Fall 1969), 107–45.
9. Jacobson, Louis S. "Earnings Losses of Workers Displaced from Manufacturing Industries." This volume.
10. ______. "Estimating the Loss in Earnings for Displaced Workers in the Steel Industry." In *Removing Restrictions on Imports of Steel*, PRI 75-2, Center for Naval Analyses.
11. Mattila, J. Peter. "Quit Behavior in the Labor Market." *Proceedings of the Business and Economic Statistics Section*, American Statistical Association, 1969, 697–701.
12. Mortensen, Dale T. "A Theory of Wage and Employment Dynamics." In *Microeconomic Foundations of Employment and Inflation*, edited by Edmund S. Phelps et al. New York: W. W. Norton, 1970.
13. Nadiri, M. Ishaq, and Sherwin Rosen. *A Disequilibrium Model of Demand for Factors of Production*. New York: National Bureau of Economic Research, 1974.
14. Parsons, Donald O. "Quit Rates over Time: A Search and Information Approach." *American Economic Review*, 63 (June 1973), 390–401.
15. ______. "Specific Human Capital: An Application to Quit and Layoff Rates." *Journal of Political Economy*, 80 (November/December 1972), 1120–43.
16. Parsons, Donald O., and Belton Fleisher. "Layoffs and Experienced Worker Unemployment Behavior." Mimeographed.
17. Pencavel, John H. *An Analysis of the Quit Rate in American Manufacturing Industry*. Princeton: Industrial Relations Section, Princeton University, 1970.
18. ______. "Wages, Specific Training and Labor Turnover in U.S. Manufacturing Industries." *International Economic Review*, 13 (February 1972), 53–64.
19. Stoikov, Vladimir, and Robert R. Raimon. "Determinants of the Differences in the Quit Rate among Industries." *American Economic Review*, 58 (December 1968), 1283–98.
20. Toikka, Richard S. "A Markovian Model of Labor Market Decisions by Workers." *American Economic Review*, 66 (December 1976), 821–34.